

Organized research in the U.S. involves billions of federal and private dollars and dozens of agencies. It also comprises large numbers of research institutions and individual investigators in a complex set of relationships with funding organizations and with one another. This report refers to that combination of investigators, sponsoring organizations, and research institutions as the research enterprise. Any effort to move that enterprise toward an ideal future demands a solid understanding of its current make-up and operation. This report concentrates primarily on the federally funded portion of this enterprise, but necessarily includes attention to broader issues as well.

For more than 50 years, the U.S. government has supported and encouraged scientific discovery through grants to researchers in laboratories and educational institutions around the nation. From its modest beginning in the late 1940s, this research enterprise has grown, matured, and evolved into a \$112-billion endeavor involving thousands of organizations and investigators representing every scientific discipline and field of knowledge. The research enterprise encompasses three main kinds of work—basic research, applied research, and development activities, collectively referred to as research and development or R&D.

The FY2003 federal budget describes **basic research** as "systematic study directed towards gaining greater knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications towards processes or products in mind." **Applied research** is "systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met."

Development is "systematic application of knowledge toward the production of useful materials, devices, and systems or methods, including design, and development and improvement of prototypes and new processes to meet specific requirements." Of all planned federal R&D spending for FY2003, about 23 percent will go to basic research, another 23 percent to applied research, and the remaining 54 percent to development and research facilities.

Size, scope, complexity, and diversity

More than 20 agencies contribute to federal investments in basic and applied research, development, and supporting equipment and facilities. According to the FY2003 Federal Science and Technology Budget, the largest research budgets are in the National Institutes of Health (\$20.3 billion), NASA (\$10.1 billion), the Department of Energy (\$8.5 billion), and the National Science Foundation (\$3.7 billion). Total federal investments in research and development represent an increase of eight percent over 2002 and more than 34 percent since 2000. Total federal R&D spending has increased 11-fold since records began to be kept in 1949, rising from \$940 million to over \$100 billion. A few recent statistics illustrate the size and scope of the enterprise.

- In 2001, the National Institutes of Health awarded more than 40,000 competitive and noncompetitive research and development grants worth \$14.9 billion to investigators at more than 2,500 research institutions. The average size of an award was \$305,000. Over 27,000 individual investigators applied for NIH's competitive awards.
- In the same year, the National Science Foundation received nearly 32,000 new proposals and made awards to about 3,400 or 10.6 percent. The median award amount was \$75,000 for a two-and-a-half-year project. This modest figure masks the range of award sizes which rise to over \$100 million for specially targeted multi-year, multi-institutional partnership programs.
- A single institution in a single year may receive and manage only a handful of small grants, or, like the University of Illinois at Urbana-Champaign, may receive from NSF alone more than 300 awards totaling over \$120 million.
- A single investigator may have research funding from multiple public agencies as well as from private or foundation sources - and each sponsor has its own goals, policies, and practices.

The research enterprise is not only large, complex, and important in its own right, it is also embedded in a political, economic, and social environment that exerts strong influences on research topics and priorities, methods and principles, and opportunities for involvement. The White House, congressional committees, academic societies, consumers and citizens, Professional Associations and interest groups all play some role. Figure 1 suggests the complexity and diversity inherent in the research enterprise. It can be thought of as an ongoing cycle of overlapping activities, each involving influential stakeholders in a variety of relationships.

The process of identifying research needs involves all stakeholders and reflects collectively the concerns of society, the priorities of political leaders, and the intellectual commitment to the discovery and pursuit of new knowledge. Selection involves the process of soliciting and encouraging research proposals, evaluating them, and

choosing a portfolio of projects that collectively addresses the needs from a variety of perspectives, using different approaches and methods. Research is conducted in a variety of settings by trained investigators whose goals include discovery, testing and validation of concepts and theories, knowledge building within and across disciplines, and the production of new tools, methods, and devices for practical use. Research results are used to advance theoretical knowledge, to generate practical solutions to problems, to train the next generation of research scientists, and to enhance the knowledge and education of the public. None of these activities is in the domain of a single stakeholder. As a result, each domain can encompass competing values, delicate negotiation, and ongoing conflict.

Figure 1. The U.S. Research Enterprise

Stresses and performance challenges

Given the size, scope, complexity, diversity, and growth of the research enterprise in the U.S., the mechanisms that support research have come under increasing stress and scrutiny. Systems, staff, and processes that were designed to handle smaller, simpler programs are now straining to support new, high-volume, high-cost programs such as information technology research (ITR) at NSF, cancer and bioterrorism research at NIH, or the climate change program partnership among NASA, the National Oceanographic and Atmospheric Administration (NOAA), Department of Agriculture, Department of Energy, and NSF. Each of these programs, and others like them, involve thousands of investigators, universities, and laboratories.

At the same time as the enterprise is developing new research models, management and accountability requirements have been strengthened with the passage of the Government Performance and Accountability Act (GPRA) and the President's Management Agenda. Both require agencies to employ performance measures that address program achievements and managerial accountability. Heightened human subjects protections place additional procedural requirements and record-keeping responsibilities on funders, investigators, and their institutions. In the research institutions themselves, the multiple business processes, rules, and expectations of different funding organizations cause high overhead and opportunity for error in processing awards and accounting for and reporting results. Several initiatives to address and simplify the multiplicity of federal grants-making activities focusing on electronic grants administration within and across various agencies. The Federal Commons Project, for example, is a single portal that consolidates access to all federal grants programs, and other aspects of grants management.

Finally, while research itself is burgeoning, traditional publication outlets for releasing research results reach only a narrow audience. They do little to communicate and demonstrate the value of R&D investments in plain language that crosses disciplines and makes sense even to much of the research enterprise, let alone to the public. These and other challenges are discussed more fully in Chapter 2.

Characteristics of the ideal research enterprise

The research enterprise is essential to continued economic growth, global competitiveness, and societal well-being. Its contributions over the past five decades amply demonstrate the value of sizable investments in science, technology, and engineering. These contributions and benefits flow from a mixed portfolio of basic, applied, and development work, with long-, medium-, and short-term time horizons. Despite its historical record of achievement and value to contemporary society, the enterprise faces broad challenges. Many specific problems and potential solutions abound. To respond to these far-reaching and interconnected challenges and problems, the enterprise will need a clear focus on the ideals to be achieved, rather than on problems to be solved. Those ideals can be stated in simple terms as characteristics of the ideal research enterprise of the future:

Invests in work that impacts significant social and scientific challenges and responds to new discoveries--

It is capable of identifying trends, convergences, and emerging needs. The ideal research enterprise is open to new ideas, but also pursues the development of past discoveries. It supports a broad portfolio of basic research that leads to new knowledge, applied research that brings that knowledge closer to useable form, and the development of tools, systems, methods, and materials that embody knowledge.

Fosters a wide network of relationships that generates relevant questions, recognizes emerging issues, and sustains significant, cutting-edge programs of work.--The ideal enterprise engages all of its stakeholders in the key processes of agenda setting, community building, and capacity development. Stakeholder groups include political leaders, researchers, research institutions in higher education and elsewhere, grants-making

organizations of all kinds, science educators, and interest groups whose concerns generate research topics and represent consumers of research results.

Puts resources into the hands of qualified grantees through value-added decision processes that are fair, quick, and open--Ideal decision processes are sensible and add something of value at every step. They are open and understandable to all interested parties. They treat proposers and their ideas fairly and take no longer than necessary to serve their stated purpose.

Develops and nurtures the human and organizational capacity to conduct research--The enterprise makes both broad and targeted investments in the size and quality of the community of scholars. It acts directly to increase the total number of scientists and engineers, to enhance the quality of doctoral education, to introduce research principles and careers at every level of education, and to support development of under-represented groups. It encourages and guides the entry of new investigators and organizations.

Takes investment risks that encourage discovery, while managing administrative risks associated with accountability--The ideal research enterprise is a master of risk management. It understands that research is a process of experimentation and discovery that often cannot be directed toward pre-determined outcomes. It therefore takes the necessary risk of investing in a wide variety of ideas, methods, and investigators who show promise, knowing that not all of them will succeed in their goals. At the same time, the ideal enterprise balances its risktaking in support of discovery with its fiduciary responsibility for enormous amounts of funding. It builds systems and controls that limit the risks of administrative error or abuse by documenting decisions and accounting for the proper use of awards and administrative funds. It manages the peaceful co-existence of these two ways of conceptualizing risk by balancing their goals and methods, and by constantly monitoring and adjusting them so that they do not work against one another.

Uses rules-based business processes that are clear and seamless for all involved--The ideal research enterprise is a highly functional business endeavor that takes an enterprise-wide view of its business processes. It recognizes the implications of both intra- and interorganizational work flows and information exchanges. It uses business processes that serve functional needs and follow explicit, well-understood rules. Each process generates, draws upon, and maintains pertinent records and information. The processes and their associated information are well integrated across functions and organizational boundaries. They support useful, cost-effective relationships among the variety of organizations involved in grants-funded research.

Puts management and support work in the hands of well-prepared individuals and organizations--Many kinds of skills and knowledge are present in the operational domain of the ideal research enterprise. Administrators, operations and support staff, program managers, financial experts, Information Technology (IT) professionals, communication specialists, data analysts, and human resource staff all play important roles. In this ideal enterprise, each kind of professional specialty is adequately staffed, well trained, and assigned the responsibilities it is best suited to handle.

Strives for excellence and welcomes innovation in its own operations--The research enterprise is self-reflective, regularly evaluates itself, and embraces intellectual, organizational, and operational experiments and innovations to constantly improve performance. As a consequence, it is constantly growing and changing.

Understands, represents, and advocates for its community--Like all important aspects of our society, the research enterprise competes for limited public attention and financial resources. The ideal enterprise is self-aware; it understands the kinds of work being done, the people and organizations involved, their needs, and their capabilities. It is activist and articulate; the enterprise mobilizes its stakeholders to advocate for policies, priorities, and resources that will sustain its contributions and its potential for discoveries that benefit society.

Recognizes and communicates its impact on the world--The ideal enterprise fully recognizes the results, outcomes, and impacts of the work it embodies. It can communicate about them within the scientific community and to society at large. It tracks research results and demonstrates in plain language how, over time, they contribute to a better life for individuals and communities. It explains the essential value of investments in basic, applied, and developmental projects and shows how each contributes to new knowledge and its practical application in business, industry, government, and community.

The characteristics of an ideal research enterprise

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